Integrated Machinery Management

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Abstract: This paper proposes a holistic, integrated approach to machinery management. Such a program is comprised of four major elements. There must be a systematic planned maintenance system for routine maintenance and condition assessment. A system must be in place to insure needed spares are available without carrying excessive inventory. Most importantly, a measurement system must collect necessary data and present it to management in such a way that they understand their problems and what action to take. Once good measurements are available, there must be a continuous improvement system to make the maintenance function more effective, the equipment more reliable and efficient, the work performed more professional and less expensive, while minimizing spares inventory carrying costs.

Key Words: Continuous improvement; integrated maintenance; machinery management; predictive maintenance; preventive maintenance; reliability engineering; spares management

INTRODUCTION: Manufacturing today is becoming increasingly competitive. Production processes have been squeezed for the last pound per hour, for one more component per shift. The production equipment itself is one of the few remaining areas in plant operation where significant gains can be made. To maintain your manufacturing leadership, you must move from a defensive strategy of maintaining the status quo to a proactive, aggressive plan to improve plant reliability and capacity. You must manage the production assets in a systematic and professional way.

Much attention has been given lately to the use of modern condition monitoring techniques such as vibration analysis and oil analysis. Many claims, most of them true to some extent, have been made for their ability to spot failures before they happen. Though these methods are powerful, it's important to remember that they must be used as part of an overall system of maintenance.

Without a complete program, only minimal, short term benefit will be gained from condition monitoring.

The most progressive, competitive manufacturing organizations see management of production assets as a potential strategic advantage. They are developing integrated machinery management programs that pull all the separate technologies and management techniques together in a way that allows them to understand where the problems are and how important they are. Knowing that, they can make plans to solve those problems permanently. Until you know what the problems are, any action taken will at best result in short term solutions. In the worst case it may make the problem worse.

I want to remind you of some of the other types of information that we should consider. Each piece is important on its own. Each area has its own techniques and tools, both hardware and software. The real advantages come from the synergy that results from combining this information.

Machinery information comes from many sources. A machinery information management system (MIMS) often consists of several parts. For purposes of this discussion, the major ones are:

- Planned maintenance system (PMS)
- Spares management system (SMS)
- Production system (PS)
- History collection system (HCS)
- Continuous improvement system (CIS)

There must be a systematic Planned Maintenance System for routine maintenance and condition assessment. A Spares Management System insures needed spares are available without carrying excessive inventory. Accurate history on maintenance expenditures and experience is essential to identify the most troublesome problems. But most importantly, to achieve the potential production improvements and reductions in cost per unit, all the information available to plant management, including history, must be *used*. This is the Measurement System. Once good measurements are available, the Continuous Improvement System guides you in making the planned maintenance function more effective, the equipment more reliable and efficient, the work performed more professional and less expensive, and in minimizing spares inventory carrying costs.

The difficult part of maintenance management is to balance the maintenance expenses and needs, while minimizing overall costs. An objective of self-assessment of your maintenance processes may be to identify opportunities to improve equipment performance or reduce maintenance costs. However, these improvements cannot be accomplished without some investment in manpower or improved technology.

Done correctly, costs may go up but sales revenue and gross profit will go up faster. The payoff from putting in place an integrated machinery management program is longer Mean Time Between Failure (MTBF), shorter Mean Time To Repair (MTTR) and shorter Mean Logistics Delay Time (MLDT). Those factors mean higher reliability and availability. This pays off in higher product throughput and lower operating expenses.

The MIMS is a system in the true sense. As can be seen in Fig. 1., it has inputs and outputs. And it has feedback. They are:

Inputs:
- Maintenance actions on the machine
- Spare parts actions
- Engineering / design change actions
- Machine operation

Outputs:
- Routine and adhoc reports
- Program improvement objectives
- Machine improvement objectives
- Personnel improvement objectives

Feedback:
Continuous improvement system

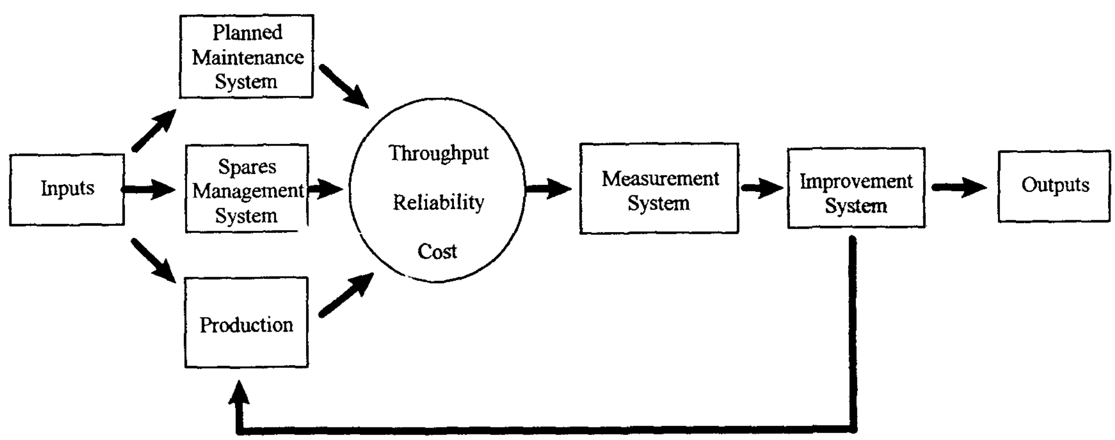

Fig. 1. Machinery Information Management System

PLANNED MAINTENANCE SYSTEM: All work is planned! If it is not pre-planned, then it is planned during execution. Pre-planning insures needed parts, materials and skills are available. Multiple trips to the tool room or store room are eliminated. Crafts are coordinated, avoiding wasted manpower caused by people standing around waiting. Work planned during execution suffers from false starts, missing parts or information and wasted manpower. Work that is not pre-planned can cost you as much as 25 times more to accomplish.

A good planned maintenance system is designed with an optimal mix of preventive (PM) and predictive (PdM) maintenance tasks. As much corrective maintenance as possible is planned to make best use of manpower and spares. The number of unplanned repairs is minimized. A good planned maintenance system will reduce the number of emergency repairs to a minimum because many of the failures that would be emergencies are found early while doing PM or PdM tasks. Because they are found before the failure occurs, they can be repaired with the least impact on production.

Preventive (Time Directed) Maintenance: FACT: Equipment that is operated can fail, and not all failures can be prevented. Preventive maintenance forms the backbone of a planned maintenance system. PM tasks are either fault finding (inspection) or preventive replacement. The routine of time directed tasks fosters discipline and focus in the maintenance organization. A well designed program has a standard daily and weekly routine that encourages systematic planning and performance of maintenance tasks.

Predictive (Condition Directed) Maintenance: A good planned maintenance system has a heavy emphasis on condition directed tasks, often called predictive maintenance. Periodic monitoring of equipment condition will optimize use of manpower, consumables and spares because work on the machine is only done when it's needed. Both installed production instrumentation and special technologies are used to monitor and trend equipment condition. Some of the most common technologies are vibration analysis, oil analysis, motor analysis and infrared scanning.

Planned Corrective maintenance: Corrective maintenance must be accomplished in the most cost effective manner possible. Because equipment problems are detected sooner by PM and PdM tasks, corrective action can be planned. Planned repairs result in much lower maintenance costs. Labor costs are lower because the crafts people start the job with all the parts and tools they need. Overtime can be reduced or eliminated. Spares costs will be lower because they don't have to be ordered on a crises basis, with the resulting high freight fees and expediting costs. And lost production cost will be lower because the repair is done during a scheduled shutdown. Even if a special shutdown has to be scheduled for the repair, it will be shorter because all parts, tools and people can be in place before production is stopped. The work will proceed more efficiently because the crafts know what they will be doing. Lost product or off quality product is minimized because production is shut down in an orderly manner rather than by a casualty. And because the line is shut down in an orderly manner, secondary, cascading failures are avoided.

Even emergency work can be planned. Some emergencies can be anticipated. For these, a preplanned work order can be on file ready to go. For repairs that are not anticipated, the savings resulting from a conscious, formal planning step can still be significant. Planning will minimize trips to the tool and store room. It can ensure all needed parts are ordered the first time, and that the correct crafts and tools are on hand.

Most CMMS systems collect general work and performance data. The various condition monitoring technologies have their own, often proprietary, supporting software. Each technology has pieces of information that are unique to it. Each of these pieces of information are important and must be captured.

SPARES MANAGEMENT (SM) SYSTEM: Spare parts are kept on hand so repairs can be made in the quickest time possible. But do you know what spare parts you have on hand? Do you know what parts you should have on hand? A good SM program has a spares allowance list (SAL) for each piece of critical equipment. The SAL differs from a Bill of Materials because it lists all the parts that should be kept in the store room to repair that machine. The lists for the individual machines are combined into a consolidated list for the whole facility. Consolidation accounts for duplicate usage of some of the parts, resulting in lower total parts inventory.

SM also provides for systematic storage, inventory control and issue of spares. As a part is issued, it is charged to the proper job order and machine. This assigns the cost of the part to the cost of maintaining the machine and is information needed to assess the usage of the part. Knowledge of usage lets you update the allowance lists as the equipment ages and conditions change. A periodic audit of spares will identify parts no longer needed or additions to the allowance because of increased usage. You will be able to adjust order points and minimum levels to insure parts are available when needed.

The Spares Management System generates several kinds of useful information. Parts should be designated as to usage and inventory management method. There can be non-stock, usage stock, insuranc stock and project stock to keep track of, each with its own management method. Storeroom management needs information on location, layout, stock catalogs, and issue/receipt. There are also other spares management actions that generate information. Spares are ordered, unused parts are turned in, kits are built for specific jobs, bills of material and allowance lists for each machine must be maintained. And the whole system must be updated as a result of engineering change orders that affect the machinery.

PRODUCTION: Production generates a number of pieces of information that can be useful to maintenance and engineering. In addition to operating temperatures, pressures, speeds and other data, the planned and actual production times and run times are important. Records of change-over, bottle-necks, product produced and operating problems provide needed information to assess program effectiveness and machine improvement.

MEASUREMENT SYSTEM: One of the difficulties in the maintenance field is objectively judging the actions of those involved. The large machines in major industrial installations are inherently reliable and their natural rate of deterioration is very low. A manager can spend very little money over a period of several years without experiencing a marked decrease in availability. He often appears to do a better job than a manager who applies a more comprehensive approach. In the latter case, corresponding expenses are visible, and have an immediate negative impact on the budget. Because machinery information is so hard to gather and present consistently, senior management does not recognize the resulting aging and deterioration until too late.

A measurement system is like the control panel of an aircraft. It tells you where you are and what the conditions you are operating in are like. Your measurements should accurately represent the current conditions. Comparing measurements from period to period, looking for trends, will tell you where you are headed. By collecting the right data and displaying it properly, the beneficial impact of maintenance can be quantified in a way that is understood and believed by upper management.

The basic requirement for good measurements is good records. A common complaint of crafts people is that they are paid to work on the machinery, not to do paperwork. At first glance this seems to be true. But the paper work involved in history collection is a vital part of understanding the equipment. The cost of the time spent filling out good history reports will be more than offset by the long term savings in improved maintenance and reliability. Good records let you know what the most expensive machines are, what the most common failure modes are, what parts to keep on hand, what machines need more or less PM or PdM. Accurate detailed history gives you the information you need to do root cause analyses of failures and fix the real problem so it doesn't reoccur. Another advantage of detailed descriptions is that they can act as a planning tool if the casualty occurs again. Good records also provide you the data needed to develop and justify your budgets. It gives you a management tool to target budget cuts to the areas where they will be most effective.

The history collection system must gather at least three types of information. Statistical information must be captured for overall analysis of the maintenance function. This includes such data as man-hours expended, parts used, consumables used. It must also capture production downtime and maintenance downtime. The information contained in detailed narrative descriptions of problem and actions taken is needed for root cause analysis. It should include how the problem was discovered, what the symptoms were, trouble shooting steps taken, repair procedures used and any special problems. Accounting information - costs, badge numbers, wage rates, special shipping costs, etc. - is needed by plant management to develop and administer budgets. It also is captured as part of the life cycle cost of the machine.

Once the history is captured, it must be used. Serious analysis of maintenance should:

- take into consideration indirect maintenance costs (costs of reduced or lost production).
- Judge the evolution of economic indicators over a prolonged period.
- Evaluate the evolution of the equipment condition over the same period.

The raw data must be manipulated to find the information that's in it. MTBF, MTTR and MLDT are calculated. Costs are summarized. Effects of varying production utilization are accounted for. The resulting measurements should be a true picture of the current situation.

CONTINUOUS IMPROVEMENT PLAN: The Continuous Improvement System is where it all comes together. In this system, the history collected is used to identify areas where maintenance can be made easier and cheaper. Unneeded maintenance or additional needed maintenance is identified. Additional training requirements, changes in logistics requirements and potential equipment redesign or modification are other results of analysis of the history. The review should not be limited to large, costly or politically visible failures. Clusters of failures should be sought out. Often several minor failures can cost as much or more than one large failure. Looking for clusters of failures and eliminating their cause will pay for itself quickly.

A Maintenance Reduction System consists of several separate but related parts. They are:

- Planned Maintenance Optimization
- Precision Maintenance
- Maintainability Improvement
- Equipment Improvement
- Logistics Improvement
- New Equipment Selection

Planned Maintenance Optimization: Plant design characteristics can create a performance limit for the plant, no matter how effective the maintenance is. However, it is also true that improper, inadequate, or too much maintenance can adversely affect performance. Over-maintenance increases direct and indirect maintenance costs by increasing voluntary production losses, speeding aging due to excess dismantling and re-assembly, and increasing the risks of damage through human error. Given these limitations, how do you establish the optimal maintenance program.?

Planned Maintenance Optimization is a formal program to review the effectiveness of the Planned Maintenance System. Using data from the measurement system, reliability information can be derived. Review of this information will identify those machines with too much or too little PM or PdM. It will assess the effectiveness of the planned tasks and recommend added tasks if needed.

Finally, this review will tell management where they should apply more expensive techniques such as Reliability Centered Maintenance, condition monitoring, machine modification and others. It can identify needed training and tools.

Precision Maintenance: Precision maintenance denotes a high level of skill and training of the crafts. Such things as use of standard procedures for bearing replacement, correct preparation of foundations before setting equipment to prevent soft foot, and using vibration to verify correct installation are examples. It also encompasses using tighter tolerances than is normal. When balancing, take the little extra time to make an extra run - it will pay off in increased bearing life. Precision alignment to increase seal life, strict cleanliness to avoid later problems because of dirt, and extra care in seating surface preparation are other examples. Analysis of the history will show where the training dollars should be spent.

Maintainability Improvement: Maintenance tasks should be reviewed to determine those that take a long time to do or that require large manpower expenditure. These tasks should be investigated to see if there are changes that can be made to make the task more economical. These might be procedures changes, special tools or jigs, or modifications to the machine. All of these improve the maintainability of the machine. Better maintainability means the machine is cheaper and safer to maintain and less problems are introduced while doing maintenance.

An example might be a task requiring periodic checking of gear tooth wear on a gear set. Because of equipment design, the job takes three men (two mechanics and an electrician) 4 hours, a total of 12 man-hours. They have to remove an interfering motor and rig a cover plate off the casing. By installing an access plate in the gear casing, the job can be done by one man in 30 minutes.

Equipment Improvement: A history of frequent failures of a machine might lead to a design change to eliminate the problem. For example, review of the history reveals that maintenance is called several times a week to unjam product on the conveyer feeding the wrapper. The product is getting cocked, and following product shoves it into the rollers. Engineering redesigns the guides to prevent the cocking, eliminating the problem. The increased production and reduction in off quality product more than pay for the modification.

Logistics Improvement: The spares usage should frequently be reviewed to assess the adequacy of the SAL's. Parts may no longer be needed because of changes to the equipment, stocking levels may need to be adjusted because of usage, additional parts may need to be added to the SAL. History can help identify parts that should be vendor stocked, vendors who are not responsive either in timeliness or quality of parts, and parts that have a high failure rate and should be substituted. Incidences of not having the proper tools, drawing or manuals will also be identified by history review. Correction of these problems will reduce the delay before the repair can start (MLDT), which means less lost production and more sales dollars.

New Equipment Selection: The best plants will monitor the life cycle costs of their equipment. As your equipment ages, there may come a time when it is more effective to replace it with new than it is to continue to repair it. A recent study by Eastman Chemical Company showed that maintenance costs can be as high as 50% to 75% of total life cycle costs. A good machinery history will give you the information needed to make an overhaul / buy decision.

SUMMARY: As we work towards an open system for machinery information management, we need to think of all the aspects of machinery information. Because a majority of our members are from the condition monitoring field or from large user organizations, there is a danger that we may become too narrowly focused

While big companies have enough people and resources to put together large projects to integrate the various sources of machinery information, most companies don't. There are 350,000 manufacturing plants in the USA, but only 35,000 have more than 100 employees. It is those 315,000 who most need our help.

One screen access to all required information will be a major step towards giving management the tools needed to intelligently set policy and improve their operation. By identifying problem areas and suggesting solutions the MIMS can start the process of continuous improvement. By collecting all pertinent information consistently, it provides a measurement system that tells management if they are on course or off course.